VOLUME VI APRIL, 1913 No. 1

OBSERVATIONS ON BRITISH RAT-FLEAS[1].

JULY—OCTOBER, 1911.

THE observations here recorded relate to rat-fleas: (I) in Suffolk and North Essex, and (II) in Cambridgeshire.

(I) The report by Messrs Strickland and Merriman has entailed a great deal of labour. The field work was mainly carried out by Mr Merriman, who, during the extreme heat of summer, was obliged to bicycle many miles, almost daily, to the different localities where the rat-catching was being conducted. It was essential, if reliable results were to be obtained, that the collector should, so to speak, be at the rat-catcher's elbow during the operations. The work of determining the many specimens of fleas collected was, on the other hand, carried out by Mr Strickland, who also shared in the field work when time permitted. The field work commenced on 2nd July, 1911, and ended on 23rd October, 1911.

(II) The report by Mr Strickland and myself upon rat-fleas in Cambridgeshire is very brief, although it took a good deal of time to collect the data upon which it is based.

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Quick Professor of Biology, Cambridge.

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[1] **Republished by permission of H.M. Stationery Office from *Forty-first Ann. Rep. of the Local Gov. Board* 1911-12, Supplement containing the Report of the Medical Officer, being Appendix B., No. 6, pp. 336–349 with 3 charts.—*Ed.***

I. REPORT ON RAT-FLEAS IN SUFFOLK AND NORTH ESSEX.

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(With 3 Charts.)

The investigations herewith reported upon were undertaken at the instance of the Local Government Board in connection with an enquiry in relation to rats and plague in East Anglia. We were commissioned to study the rat-fleas in the suspected plague area, determining more especially their species and the numbers in which they occurred.

In India, the evidence brought by the Indian Plague Commission has proved that fleas are the active agents in transmitting plague from rat to rat: the number of fleas which occurs on rats in India bears a direct relation to the plague incidence among these rodents. The established connection between rat plague and human plague incidence and the fact that *Xenopsylla cheopis*, the common Indian rat-flea, readily attacks man have led to the now generally-accepted conclusion that fleas play an important part in the epidemiology of human plague, especially in India.

In England, Martin and Rowland (1910) found that rat plague prevailed chiefly in those parts of Suffolk where fleas were most numerous on rats. They moreover found *B. pestis*-like organisms in the gut of fleas removed from plague rats. We find that British rats are infested mainly by two species of flea, *Ceratophyllus fasciatus* and *Ctenophthalmus agyrtes*, of which the former only has been proved by experiment to be capable of transmitting plague from rat to rat in India. In that country *X. cheopis* is, however, chiefly concerned in the spread of rat plague. Experimental evidence is still wanting to prove that *C. fasciatus* is capable of transmitting plague from rat to rat under the conditions prevailing in England. It is the only species of rat-flea in this country which has been found to attack man readily under experimental conditions; consequently, if evidence is forthcoming that it serves as a vector of *B. pestis* from rat to rat in England this flea would also have to be regarded as a potential transmitter of the plague bacillus from the rat to man.

METHODS.

Collecting the fleas from rats. It was necessary for the purpose of our investigation to accompany the official rat-catchers of the Local Government Board into the field so as to obtain an accurate flea-census. Although trapping was extensively used, most of the rats were captured by ferreting their runs. We were obliged to be present when they were killed because as soon as a rat dies the fleas begin to abandon it. It is, therefore, essential that the fleas should be collected immediately upon the death of the host if a true estimate of their number is desired.

The outfit for collecting consisted of:

(*a*) Clean calico bags with string attached.

(*b*) Fine forceps and camel-hair brushes.

(*c*) Small corked tubes containing 50 % spirit carried in a box provided with holes for the reception of the tubes.

(*d*) Slips of paper, which were duly numbered in pencil and dropped into each tube, in accordance with the numbers given to the rats.

The rats, immediately upon being killed, were dropped into the bags, which were firmly tied up to prevent fleas from escaping. The bags containing the rats were subsequently placed in tins and a little chloroform was added before closing the lid. The fleas now abandoned their hosts and died after a few minutes, so that they were easily collected upon opening the bag. Fleas from each rat were put into a separate tube for subsequent examination. The method we have described ensured our obtaining an accurate flea-census based upon the numbers and species of fleas found upon each rat.

Determination of the fleas. The fleas found upon the rats were determined by microscopic examination, a Zeiss binocular dissecting microscope being used for the purpose. For examination it is best to render fleas transparent, and this is most conveniently effected by placing them in strong phenol solution, after drawing off the alcohol in which they are preserved. They may require 24 hours to clear, after which they may be transferred for some minutes to clove oil and thence to balsam if permanent mounts are required. The clearing process renders the internal structures of the male and female genital organs visible through the chitinous integument, whilst the external segments, which are also of specific importance, remain clearly visible.

The Rat. All the fleas which we examined came from *Mus decumanus.* It is well known that it is a difficult matter to catch many of these animals during the summer months, and recent attempts to exterminate them in the suspected plague area seem to have reduced their number. On some days we were occupied all day in the field without finding a single rat.

RESULTS.

The results of our investigation were as follows:

(1) About three out of every four rats harboured fleas; 822 rats were examined.

(2) The average number of fleas per rat was almost exactly four; 3293 fleas were collected.

(3) Of the rats which were captured, one harboured 105 fleas, and several rats had 30 to 40 fleas upon them.

(4) Rats captured on "model," or well-kept farms, had not fewer fleas upon them than others captured elsewhere. The rat from which 105 fleas were taken was caught on a "model" farm.

(5) The average number of fleas per rat in various groups of parishes and in the Borough of Ipswich, according to the magnitude of the number, is given in Table I. Whether plague-stricken rats were present or not in these districts is indicated by a + or – sign. We can give no explanation of the variation of the flea-average per rat in the various districts.

(6) There was a definite seasonal variation in the number of fleas per rat and in the percentage of rats infested with fleas (*see* Chart I, showing eight-weekly periods). There was a corresponding variation in the maximum and minimum temperatures, in the grass-thermometer readings, and in the atmospheric humidity[1].

The following table shows the figures obtained during the two eight-weekly periods 2nd July to 26th August and 27th August to 21st October, 1911.

	2nd July to 26th August	27th August to 21st October	Fall
Average maximum temperature	78° F.	68·5° F.	9·5° F.
,, minimum ,,	57·5° F.	49·75° F.	7·75° F.
,, grass thermometer ...	50·5° F.	42·5° F.	8·0° F.
Atmospheric humidity ...	10·90	9·33	1·57
Percentage of rats infested ...	80·	70·	10·
Average fleas per rat ...	4·5	3·4	1·1

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[1] Earth-thermometer readings are not recorded here because the instrument at our disposal proved to be unreliable.

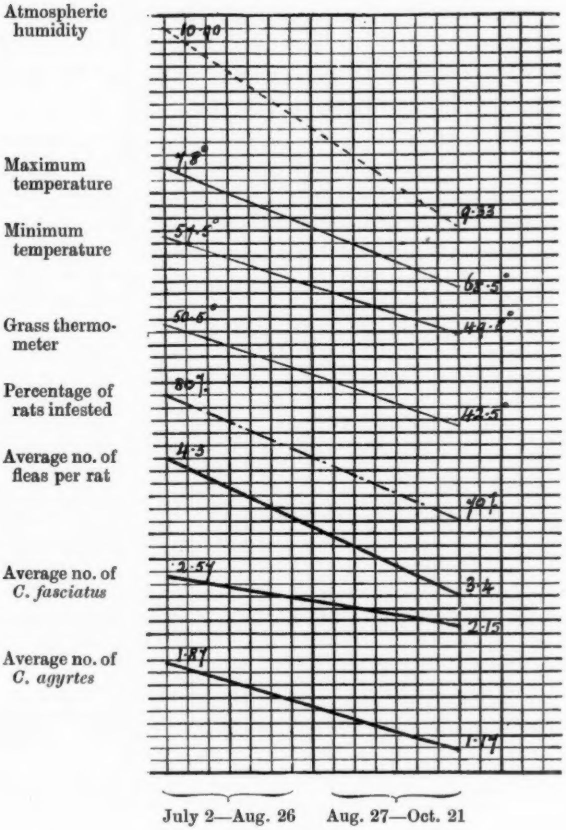

Chart I.

If we chart our observations in four-weekly periods (see Chart II), or in calendar months, the average-fleas-per-rat line follows fairly closely the maximum temperature. This remained about the same for July and August and then declined in September and October. The curve of atmospheric moisture and the grass-thermometer readings showed a sharp rise during the second month (August), but the average number of fleas per rat was unaffected. On the other hand, the percentage of flea-infested rats increased so that the absolute number of fleas caught was much greater in August than in July. During September and October there was a general decline in all our figures, but we cannot say exactly what the clearly-marked seasonal variation in the average number of fleas per rat was due to, whether to the temperature, humidity[1], or to a combination of these. We think the temperature the more important factor, but this point could only be settled by more extended observations.

For the purpose of comparison with our results we have charted the average number of fleas per rat found by Martin and Rowland during November and December, 1910, in the same part of Suffolk, when the temperature and humidity had declined to a still lower point than they had in October, 1911, during our observations.

TABLE I.

No.	District	Comprising	No. of rats examined	Average fleas per rat	Plague Present(+) Absent (-)
1	Nacton ...	Nacton Parish	22	6·5	–
2	Tuddenham ...	Swilland, Witnesham, Culpho, Tuddenham, Akenham, Claydon.	39	6·0	–
3	North Essex ...	Lawford, Ardleigh, Dedham, Langham, Boxted, Great Horksley.	40	5·8	–
4	Tattingstone ...	Tattingstone, Brantham, Wherstead, Belstead.	54	5·3	–
5	Bawdsey ...	Bawdsey, Alderton	30	5·3	+
6	Hollesley ...	Hollesley, Shottisham, Boyton ...	32	5·1	–
7	Sutton ...	Sutton Parish	22	5·0	+
8	Freston-Shotley	Freston, Holbrook, Harkstead, Shotley, Woolverstone, Chelmondistone.	35	4·8	+
9	Rushmere ...	Rushmere Parish	49	4·3	–
10	Bramford ...	Bramford, Hintlesham, Holton, Sproughton, Great and Little Wenham, Capel St Mary	45	3·8	–
11	Kesgrave ...	Brightwell, Kesgrave, Martlesham ...	69	3·7	–
12	Playford ...	Playford Parish	45	3·6	–
13	Felixstowe ...	Walton, Felixstowe	45	3·2	–
14	Framlingham ...	Rendham, Swefling, Parham, Easton, Earl-Soham.	100	3·2	–
15	Newbourne ...	Foxhall, Newbourne, Bucklesham, Purdis Farm, Waldringfield.	34	2·8	+
16	Bentley ..	Bentley, Washbrook, Copdock, East Bergholt.	45	2·7	+
17	West Suffolk ...	Boxford, Assington	11	2·6	–
18	Melton ...	Melton, Hasketon, Ufford	47	1·9	–
19	Ipswich ...	Ipswich Borough	22	1·6	+
20	Boulge ...	Boulge, Bredfield	30	0·6	–

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[1] The Indian Plague Commission, whilst working at Belgaum, India, found that humidity, within certain limits of temperature, played some part in the increase of fleas. This increase occurred a little time after the increase of humidity.

(7) The majority of fleas were found on the hinder parts of the rat, so that primary buboes, when they occur, might be expected to develop chiefly in the groin, on the assumption that fleas served as vectors.

THE SPECIES OF RAT-FLEAS.

With regard to the species of fleas found on rats in the suspected plague area, we shall (I) give a list of the species and their numbers which we found, and (II) our observations upon each species, adding a few notes by other authors on these species.

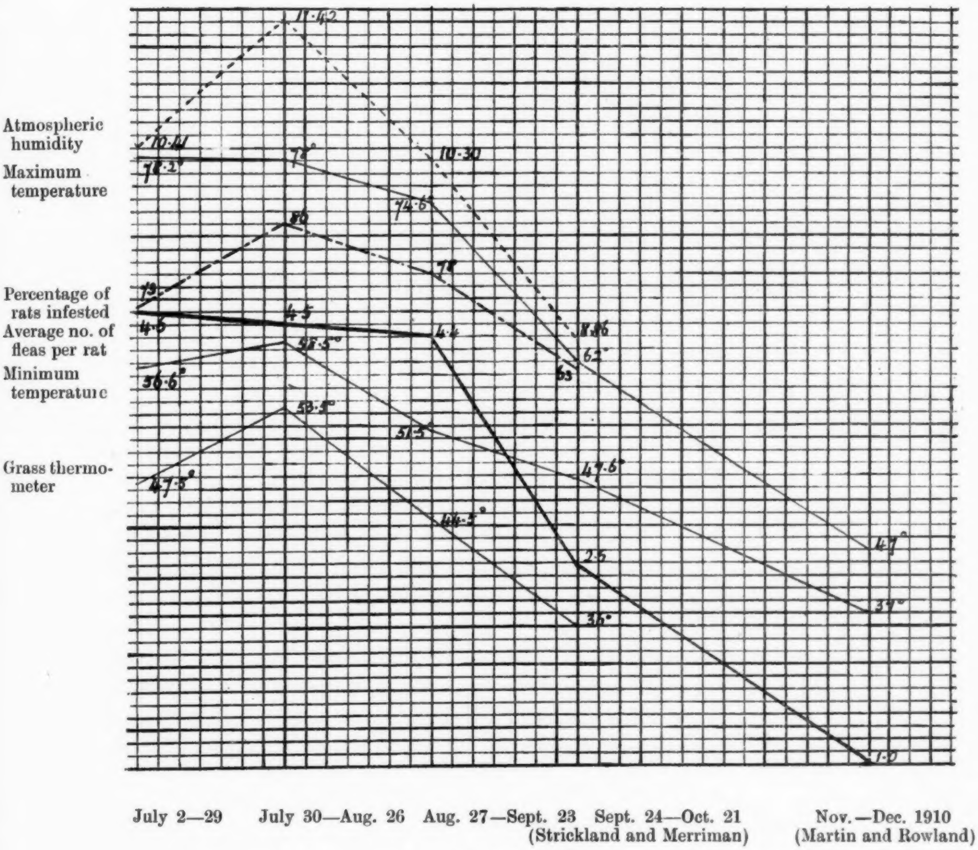

Chart II.

(I) The great majority belonged to two species only. The following table shows the numbers of each species found:

		No. collected
1.	*Ceratophyllus fasciatus*	1986
2.	*Ctenophthalmus agyrtes*	1257
3.	*Ceratophyllus mustelae*[1]	17
4.	*C. walkeri*[1]	8
5.	*Archaeopsylla erinacei*[1]	7
6.	*Ctenophthalmus pentacanthus*[1]	3
7.	*Ctenopsylla musculi*	3
8.	*Pulex irritans*	2
9.	*Hystrichopsylla talpae*	2
10.	*Ctenocephalus canis*	2
11.	*Ctenophthalmus bisoctodentatus*[1]	2
12.	*Ceratophyllus gallinae*[1]	1
13.	*C. hirundinis*[1] (?)	1
14.	*Palaeopsylla sorecis*[1]	1
15.	*P. minor*	1
		3293

(II) *Observations made on the various species of fleas found on rats.*

Ceratophyllus fasciatus (*Pulex fasciatus* Bosc d'Antic, 1801), Hilger, 1899.

The number of this species found on grown-up rats recently killed was 1986 from 822 rats—an average of 2·42 per rat.

Besides this, about 70 per cent. of the fleas caught on "nestling" rats were of this species, while of the fleas taken from rats found dead, either of injury or disease, about 90 per cent. were *C. fasciatus*. It would appear from this that *C. fasciatus* deserts a dead rat later than do other species. One of the dead rats was picked up in a yard in which many others lay dead, one of which was subsequently found to have had plague; this rat was infested by 37 fleas, although it was quite cold.

In the various districts mentioned in the table we could find no correlation between the sporadic cases of rat plague and the average number of *C. fasciatus* per rat. In view of the fact that this species bites man, we will here give the average number collected in each district.

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[1] Found on *Mus decumanus* for the first time. Rothschild (1910) does not record *Ceratophyllus mustelae*, although Tiraboschi (1904) does so. We have accepted Rothschild's authority in this matter.

TABLE II.

Giving the average number of C. fasciatus *per rat collected in each district.*

	Rat Plague: Present (+) Absent (–)	District
4·4	+	Sutton.
4·2	–	Great Horksley, Boxted, Langham, Dedham, Ardleigh, Lawford.
3·7	+	Alderton, Bawdsey.
3·5	–	Belstead, Wherstead, Tattingstone, Brantham.
3·4	–	Nacton, Levington, Stratton Hall.
3·1	–	Kesgrave, Martlesham, Brightwell.
2·5	+	Foxhall, Purdis Farm, Bucklesham, Newbourne.
2·4	+	Freston, Woolverstone, Holbrook, Chelmondiston, Harkstead, Shotley.
2·4	–	Rushmere.
2·4	–	Playford.
2·1	–	Holton, Capel, Great and Little Wenham, Chattisham, Hintlesham, Sproughton, Burstall, Bramford.
2·0	–	Earl-Soham, Framlingham, Easton, Parham, Gt Glenham, Swefling, Rendham.
1·9	–	Claydon, Akenham, Whitton, Witnesham, Swilland, Culpho, Tuddenham, Westerfield.
1·8	+	Washbrook, Bentley, Great Bergholt.
1·6	–	Hasketon, Melton, Ufford.
1·5	+	Ipswich.
1·3	–	Shottisham, Hollesley, Boyton.
1·0	–	Walton, Felixstowe.
0·3	–	Boulge, Bredfield.
0·2	–	Boxford, Assington.

The seasonal variation of *C. fasciatus* is indicated in Chart I for eight-weekly periods. It dropped from 2·58 per rat to 2·15 as the temperature and humidity fell. Chart III shows the variation per calendar month. There was a *rise* in the average number per rat during September, although the temperature showed a decrease. About 200 rats per month were examined, so that the average given was probably a real one.

Apparently *C. fasciatus* is the most prevalent flea occurring on rats in outhouses, etc., about human habitations, for of those fleas taken from rats caught in these situations 72 per cent. belonged to this species. Yet it appears to hold its own in the country-side, for of the fleas taken from hedgerows, etc., 48 per cent. were of this species. We obtained altogether 1986 specimens of *C. fasciatus*, of which 68 per cent. came from outhouses, etc., and 32 per cent. from the fields; this is in striking contrast to the other species, 39 per cent. of which came from the buildings and 61 per cent. from the hedgerows. These figures possess a certain practical importance which will be discussed later.

We found *C. fasciatus* on the following hosts:

Host	No. of occasions	No. of individuals
Man	3	4
Stoat	1	1
Mouse	1	2
Ferret	4	121
Rabbit	3	4

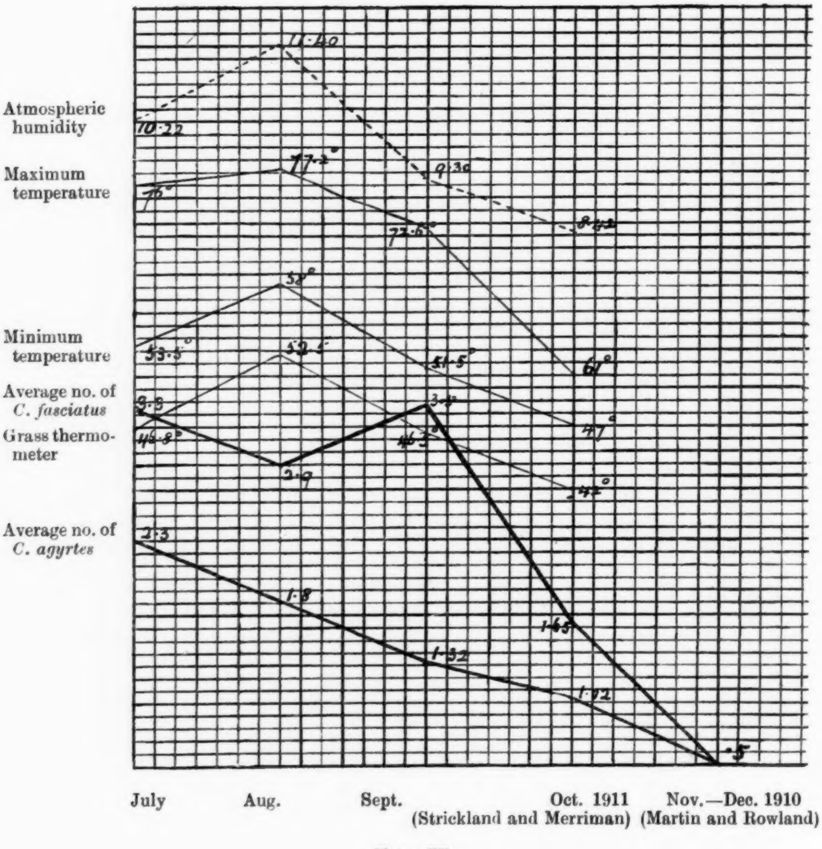

Chart III.

In addition to the above it has been found by other observers on

- *Mus silvaticus* (long-tailed field mouse).
- *Microtus agrestis* (field vole).
- *Myoxus nitela* (garden dormouse).
- *Myoxus glis* (squirrel-tailed dormouse).
- *Cricetus frumentarius* (hamster).
- *Mustela foina* (beech martin).
- *Mustela putorius* (pole-cat).
- *Crossarchus fasciatus* (banded mongoose).
- *Arvicola savii* (vole species).
- *Pitymys subterraneus.*
- *Canis lagopus* (arctic fox).

This species, according to Chick and Martin (1911), and Martin and Rowland (1911), readily bites man; and that is also our experience. It thrives on the rat. One of us (C. S.) has raised it with ease on the rat for two or three years past.

The Indian Plague Commission found that this species in India can transmit plague from rat to rat (***Mus** rattus*), two experiments having been successful.

Ctenophthalmus agyrtes (*Typhlopsylla agyrtes* Heller, 1896) Wagner, 1902.

According to Chick and Martin, and Martin and Rowland, this species does not bite man. It was first discovered in fair numbers on rats in Cambridgeshire in 1908 by Nuttall and Strickland, but it nevertheless seems to be widely distributed and nowhere scarce. The rat would, therefore, appear to be a true host for it. With regard to its other hosts, we have taken it from a *stoat* (three specimens) and from a *ferret* (one specimen); while other observers have noted it from the following hosts:

- *Mus musculus* (mouse).
- *Mus silvaticus* (wood mouse).
- *Evotomys glareolus* (bank vole).
- *Arvicola amphibius* (water vole).
- *Microtus arvalis* (continental field vole).
- *Sorex vulgaris* (common shrew).
- *Crossopus ciliatus* (water shrew).
- *Talpa europaea* (mole).
- *Mustela vulgaris* (weasel).
- *Mustela putorius* (pole-cat).

From 822 rats 1257 fleas were taken—an average of about 1·5 per rat. We can find no correlation between the presence of plague in rats in certain districts and the average number of *C. agyrtes* there any more than we could with *C. fasciatus.* Thirty-five *C. agyrtes* were taken from "nestling" rats (about 30 per cent.), while only five were taken from about 30 rats dead of injury or disease. They may leave their host very rapidly after its death.

The seasonal variation of *C. agyrtes* is shown in Chart I to be apparently dependent on temperature and moisture. In Chart III, however, it is seen that although there is a steady fall from month to month in the average number of fleas per rat, yet the temperature and humidity records do *not* show the same curve. We cannot explain this. We have put in our chart the figures which Martin and Rowland obtained during November, 1910, to show the still further fall in the degree of infestation with *C. agyrtes.*

July, 1911	2·31	fleas per rat	(154	rats).
August, 1911	1·80	,, ,,	(229	,,).
September, 1911	1·32	,, ,,	(202	,,).
October, 1911	1·11	,, ,,	(190	,,).
November—December, 1910 ...	0·5	,, ,,	(500	,,).

The proportion of the sexes was slightly lower for the females than in *C. fasciatus.* There were 57 per cent. females and 43 per cent. males for the whole period; and for each month the same proportion, almost exactly, prevailed as in *C. fasciatus.*

C. agyrtes apparently is a "country" flea, for while, in the buildings, only 28 per cent. of the fleas taken were of this species, in the hedgerows 52 per cent. were *C. agyrtes.* Of the total number of *agyrtes,* 61 per cent. came from hedgerows and 39 per cent. from buildings, being the reverse of what was observed in the case of *C. fasciatus.* Martin and Rowland also found a preponderance (about 60 per cent.) of *C. agyrtes* in a lot of fleas taken from rat-nests in hedgerows.

Ceratophyllus mustelae (*Pulex mustelae* Dale, 1878) Wagner, 1898.

We found 17 specimens of this species upon 16 rats in the following parishes:—Playford (2), Bentley (3), Felixstowe (3), Kesgrave (1), Rushmere (2), Brantham (2), Rendham (1), Assington (1), Holbrook (1), Tattingstone (1).

Its common host is the weasel (*Mustela vulgaris*).

Ceratophyllus walkeri Rothschild, 1902.

This species was taken on only eight occasions from as many rats in the parishes of Bentley, Rushmere (3), Tattingstone, Brantham, Lawford, and Felixstowe. On one of the rats it was found in company with *C. mustelae*, both species of flea probably having been picked up from the trail of a weasel.

C. walkeri has also been found on the following hosts :—*Mus musculi*, *Mustela vulgaris*, *M. erminea*, *Sorex vulgaris*, *Microtus glareolus*, *M. amphibius*, *Arvicola sp.* *M. vulgaris* is, however, considered its true host.

Archaeopsylla erinacei (*Pulex erinacei* Bouché, 1835).

We found *A. erinacei* on two rats, once singly and once six of them, in the parish of Martlesham and the borough of Ipswich. This is the common hedgehog flea. Satunin found it once on *Mus alexandrinus*.

Ctenopsylla musculi (*Pulex musculi* Dugès, 1832).

This, the common mouse flea, was only found three times on rats in East Suffolk. Three specimens were collected : two in Culpho and one in Parham. We found it once on mice in Framlingham and it has also been taken from *Mus silvaticus* and *Mus rattus*.

According to Tiraboschi it does not bite man.

Ctenophthalmus pentacanthus (*Typhlopsylla pentacanthus* Rothschild, 1898) Wagner, 1902.

The true host of this flea is stated to be the field vole, *Microtus agrestis*. It occurs also on *Mus silvaticus*, *Talpa europaea*, and *Mustela vulgaris*. We have found it on three occasions on *Mus decumanus*, each time singly, in Tuddenham, Walton, and Boxford.

Pulex irritans (*Pulex vulgaris* Linnaeus, 1746) Rothschild, 1908.

The natural host of this flea is *man*. We have found it twice on rats (two specimens) in Rushmere and Playford. Its other hosts are numerous, but according to Rothschild the badger is a true host. A doubt has been expressed with regard to this species serving as a plague vector from man to man, on the ground that the degree of septicaemia occurring in human plague is insufficient to infect the flea.

Hystrichopsylla talpae (*Pulex talpae* Curtis, 1826).

H. talpae was found on two rats caught alive in Dedham and Hollesley, respectively, and on one found dead in Lawford. Its other hosts are as follows:

Microtus arvalis.
,, *agrestis.*
Talpa europaea (its true host).
Sorex araneus.

Ctenocephalus canis (*Pulex canis* Curtis, 1826–1832).

This species, the common dog flea, was twice found by us on rats in Kesgrave and Tuddenham. Three specimens were caught on a dog at Holton. Its other hosts are *Otocyon megalotis, Canis lagopus, Nasua solitaria* and *Felis jaguarondi*; and it has been found in the nest of the great tit, *Parus major.*

Ctenophthalmus bisoctodentatus (Kolenati, 1862).

Two specimens of this species were found by us on rats in Great Horksley and Bentley, whilst two others were taken from a rat in Hollesley.

Ceratophyllus gallinae (*Pulex gallinae* Schrank, 1804) Rothschild, 1900.

This is the flea which infests fowl and poultry runs. It readily attacks man—a fact well-known in the country. Its normal host must, however, be considered to be the domestic fowl; but its tastes seem to be catholic, as it is found in the nests of many species of birds. In Cambridge, for instance, we have found it in a number of tits' nests (*Parus major*). It has also been taken from the bat (*Vesperugo noctula*) and from the field mouse (*Mus silvaticus*), but it has not, hitherto, been found on the rat. This is evidence that the rat cannot be regarded with favour by this flea, for the two must often be brought into contact in the farm-yard. Indeed, we have caught a batch of rats (Holton) in a barn literally swarming with *C. gallinae*, but they did not harbour a single flea of this species. Only on two occasions did we find this flea upon rats: once upon a rat caught alive in Rushmere and once upon a rat found dead in Bentley. We have taken it several times from man in large numbers, also from the dog once (at Holton), and, finally, from barns and the hole of an old oak tree.

Ceratophyllus hirundinis (Curtis, 1832) Rothschild, 1900.

This species is represented in our collection by a headless specimen. It has only been found previously on sand-martins and swallows (*H. urbica* and *H. rustica*).

Palaeopsylla sorecis (*Ctenophthalmus sorecis* Dale, 1878) Dampf, 1910.

This species was taken once from a rat in the parish of Swefling.

Palaeopsylla minor (*Ceratophyllus minor*), Dampf, 1910.

We have captured this flea once on *Mus decumanus* and once on the stoat. It has previously been taken from *Mustela putorius*.

Species of fleas found on other hosts than rats[1].

The species of fleas referred to in the foregoing pages have been found by us to occur on the following hosts other than rats:

Man	*Pulex irritans, C. gallinae, C. agyrtes, C. fasciatus.*
Stoat	*P. minor, C. agyrtes, C. fasciatus.*
Mouse	*C. musculi, C. fasciatus.*
Dog	*C. canis, C. gallinae.*
Ferret	*C. fasciatus, C. agyrtes.*
Rabbit	*C. fasciatus, C. agyrtes, Spilopsyllus cuniculi*[2].
Hedgehog	*C. erinacei.*

From the point of view of their numbers only, *C. fasciatus* and *C. agyrtes* appear to be the only two species which could have any practical significance in the epidemiology of plague, yet the other species which we found might become important another year or under other conditions. A species rare one year may become dominant another. For instance, Tiraboschi, Verjbitski, Gautier and Raybaud, and Tidswell have all reported on the great prevalence of *Ctenopsylla musculi*, but we only collected three specimens of this species.

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[1] Fleas were also found in the following situations away from any host:

Barn	*C. gallinae.*
Hole of tree	*C. gallinae.*
Rats' nests	*C. fasciatus, C. agyrtes.*

[2] *Spilopsyllus cuniculi* (*Pulex cuniculi* Dale 1878). This species has been previously found on the rabbit, cat, and rat. We obtained one specimen from a rabbit but *none from the rat*. Martin and Rowland state that it bites man.

The species of fleas, granted they are numerous enough, are only important if they bite hosts susceptible to plague infection, and so are able to transmit the disease from one to another of these hosts.

Of the species which we found on rats all, with the exception of *C. fasciatus* and *C. agyrtes*, had perhaps only an accidental connection with the rats, and possibly never bite the rat; we cannot, however, give certain evidence of this. Of the species which we rarely found on the rat, *C. musculi* and *S. cuniculi* are the common mouse and rabbit flea respectively, and as the mouse and rabbit are subject to epizootics of plague these fleas probably serve as vectors of the bacillus. *S. cuniculi* is said to bite man, in which case plague among rabbits becomes directly dangerous to man. Plague among mice must be transmitted to rats or other hosts by the agency of a flea common to the two species in order to be dangerous to man.

C. fasciatus, being parasitic on the mouse and rabbit, may sometimes be the cause of the transmission of the disease between these hosts.

C. agyrtes, in view of its numbers, is the next most important species, but it does not bite man. The significance, therefore, is restricted to the possibility of its transmitting and keeping up plague from rat to rat.

Other ecto-parasites of rats.

It is not probable that ecto-parasites of rats, other than fleas, have any significance in the epidemiology of plague; but we may here mention those which we found:

Acarina were the most abundant of other ecto-parasites, occurring on about 100 rats. There were one or two Coleoptera, and a very few Anopleura (lice). We did not find more than five rats with lice out of many hundreds examined[1].

Ticks. Three female specimens of *Ixodes tenuirostris* from two rats; found for the first time on rats, their usual hosts in this country being small mammals (shrews, harvest mice, voles). (Determined by G. H. F. Nuttall.)

Other Mites. Mostly *Haemogamasus hirsutus*, the common species found in moles' nests; *Gamasus coleoptratorum; Gamasus terribilis; Gamasus* sp.? nymph. (Determined by N. D. F. Pearce.) *Notoedres* sp., the cause of ear-scabies.

Anopleura. Haematopinus spinulosus; Haematopinus sp.?

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[1] As many of the rats were found by Drs MacAlister and Brooks to be infected with *Trypanosoma lewisi*, it is interesting to note the scarcity of lice, as these are credited by some authors to be the usual carriers of the trypanosomes.

Summary.

To summarize our principal observations made in the course of the investigation into the rat-fleas of the suspected plague area of East Suffolk, July—October, 1911:

(1) We found an average of four fleas per rat: 822 rats were examined and 3293 fleas taken.

(2) The average was subject to a local variation (0·6 to 6·5).

(3) 15 species of fleas were taken from the rats, but of these there were only two species, *C. fasciatus* and *C. agyrtes*, which occurred in any numbers.

There were *C. fasciatus* 1986 or about 60 per cent.
C. agyrtes 1257 „ 38 „
Rare species 50 „ 2 „

(4) The average number of fleas per rat and the percentage of rats infested by fleas showed a well-marked seasonal variation, there being a considerable decline in the numbers as the cooler weather came on. *Ceratophyllus fasciatus* and *Ctenophthalmus agyrtes* both participated in a similar way in this variation.

(5) *C. fasciatus* is chiefly found on rats caught near human habitations; *C. agyrtes* on those caught in the hedgerows.

In conclusion, we wish to tender our best thanks to all those gentlemen who have helped us in our work. Prof. G. H. F. Nuttall, F.R.S., very kindly aided us in organising the work and in the revision of our manuscript; Dr A. Eastwood, on behalf of the Local Government Board, placed at our disposal the material upon which we made our observations; Dr A. Pringle, Medical Officer of Health for Ipswich, kindly supplied us with the meteorological records of that town; Mr C. J. Huddart, in his administrative capacity, gave us much assistance; and the Hon. N. Charles Rothschild confirmed some of our determinations.

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II. REPORT ON RAT-FLEAS IN CAMBRIDGESHIRE.

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The following record relates to fleas collected from rats in and about Cambridge during the period 3rd March, 1909, to 20th November, 1911. We had difficulty in obtaining rats in Cambridge during the year 1911 owing largely to the high price asked by professional rat-catchers who usually sell them for sporting purposes. We have, consequently, included data collected by us during the two years before this investigation was undertaken on behalf of the Local Government Board.

With regard to the species of fleas collected from the rats, by far the larger numbers were *C. agyrtes*, especially in the case of the rats captured at Cherryhinton Brook. A few *C. fasciatus* and but one specimen each of *P. irritans* and *C. bisoctodentatus* were found on the rats. The largest numbers of fleas per rat (*C. agyrtes*) were captured in February and March.

		Locality	No. of rats examined	No. of fleas collected	Average No. of fleas per rat
1909:	March 3	Cherryhinton Brook	2	5	2·5
	,, 9	,,	27	54	2·
	,, 18	,,	1	5	5·
	,, 19	,,	1	33	33·
	April 29	,,	4	3	0·7
	May 11	,,	3	3	1·
	June 7	,,	3	2	0·6
	,, 12	,,	2	10	5·
	,, 22	,,	6	11	1·8
	July 6	,,	5	2	0·4
	August 3	,,	1	3	3·
	,, 24	Chesterton ...	3	1	0·3
	,, 31	Cherryhinton Brook	2	2	1·
	September 8	,,	1	2	2·
	,, 11	,,	2	12	6·
	October 12	,,	5	9	1·8
	,, 29	,,	3	7	2·3
	November 10	,,	4	5	1·2
	,, 28	,,	9	18	2·
	December 15	Comberton ...	11	5	0·4
1910:	February 7	Cherryhinton Brook	2	23	12·5
	,, 28	,,	2	2	1·
	March 9	,,	1	15	15·
	,, 22	,,	4	12	3·
	June 21	,,	2	5	2·5
	August 15	,,	4	12	3·
	November 14	,,	3	3	1·
1911:	February 15	,,	6	9	1·5
	,, 28	,,	3	5	1·6
	October 28	,,	1	5	5·
	September 15	Chesterton ...	5	6	1·2
	November 12	Milton Road ..	10	4	0·4
	,, 20	Wilbraham ...	12	4	0·3
		Totals	150	297	2·